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The development of the anti-tank rocket Red Planet

J. Lyall

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3 A.R.D.E. REPORT (P)17/57

4 The development of the anti-tank rocket Red Planet

5 J. Lyall (P5)

6 August 1957

Summary

This report describes briefly the development to date of the Infantry Anti-Tank Rocket, Red Planet. The calibre developed is 4.5 inch.

The individual sections deal with the problems in the design of the rocket motor, the fuze and the hollow charge warhead.

The report concludes with an assessment of the overall performance of the weapcn in its present form.

Approved for issue:

D. H. Chaddock, Principal Superintendent "P" Division

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1. THE REQUIREMENT

The military chacteristics required by an anti-tank weapon for the Infantry Platoon were detailed in Appendix J to War Office Policy Statement No. 9. In the form relevant at the outset of this development the specification may be summarised as follows:-

(a) General:- To provide a light weight anti-tank weapon and ammunition for use by the infantry platoon, capable of putting out of action the heaviest types of tanks likely to be met in the future.

(b) Order of Priority:-

(i) Destructive Capacity

(ii) Range and Accuracy

(iii) Weight and Size

(iv) Rate of Fire

(c) Definitions:-

(i) Destructive Capacity:- to defeat the tank i.e. one or more of the following:-

Crew incapable of using the weapons and driving tank

Tank unable to move or

Weapons unable to be used.

This is taken as the ability to defeat 152 m.m. (6") of armour at 64^{o} coupled with the best possible performance against skirting plate.

(ii) Range and Accuracy:- A 75% chance of a first hit against a 7'6" square target stationary at 500 yards, with the weapon in the hands of a well trained soldier under battle conditions. If necessary this order of accuracy will be accepted at 300 yards.

(iii) Weight and Size:- As light and small as possible with the following maximum parameters.

Length of launcher - 60"

Weight of launcher plus 3 projectiles - 60 lb. Launcher not to exceed 25 lb.

Weight of launcher plus 2 projectiles - 70 lbs., provided the 500 yard requirement is met.

(iv) Rate of Fire:- Ten aimed rounds per minute for one minute.

(d) Temperature Limitations:- Use and storage with normal and extreme ranges as for War Office Statement No.100 Appendix A.

2. WEIGHT AND SIZE

It is well to begin by stating that the development of the Infantry Platoon Anti Tank Rocket has been carried out against a background of doubt and controversy as to the interpretation of the specification, i.e. the emphasis to be placed on the conflicting requirements of lethality and velocity as against weight and size bearing in mind the order of priority stated. In deciding the minimum calibre of ammunition which would meet the full lethality requirement there was the technical difficulty in the early stages of estimating what improvement in warhead performance could be made available in time to be incorporated in the final design. The problem, a fundamental and most important one, is basically the size and weight of equipment that the infantry soldier can carry without reducing his prime requirements of mobility and dash.

This development to meet the above specification was commenced in December 1949 on what subsequently proved to be a pessimistic forecast, at a 5" calibre. This calibre was based on the figures available at that time for the U.S. M28 - 3.5" H.E.A.T. rocket. These suggested that although a "K" factor of about 3.5 was obtained when attacking near the normal, this figure fell off at higher angles of attack to 2.9 at 55° and 2.0 at 60°. The assumption was made that with a faster acting electric fuze, the 2.9 value could be maintained up to 64°. This required an effective cone diameter for a hollow charge of 4.7" to defeat the target of 6" at 64° (13.7" in the line of the jet) and indicated a full calibre of 5 inches. The first projectile trials with the 5 inch head with a new fast operating electric fuze, showed however that the performance was much better than the estimates and in December 1951 the decision was taken to stop all further work on the 5" calibre and to commence a new design based on 4.5" calibre. The new calibre was decided upon as a result of two main considerations, as follows:-

(1) A series of field trials had been arranged and carried out by the School of Infantry in the spring of 1951 using material provided by the Design Department. As a result the following recommendations had been made.

(a) From the point of view of handling and portability Red Biddy (an alternative design to Red Planet), in a calibre of 5" was acceptable.

(b) A 5" Red Planet was not acceptable, but a 4.5" size would be an insurance against the failure of the Red Biddy project which was of a more unorthodox design.

(ii) At the Tripartite informal discussions held at Fort Monroe in November 1951 it was agreed that the penetration requirement for the platoon anti tank rocket should be standardised at 6" at 64°. At the Tripartite Conference on Armour and Bridging held at Fort Monroe in October 1951 it had been agreed that in the interpretation of this requirement an overmatch equivalent to 2" of armour in line with the jet was necessary to ensure lethal damage behind the main target plate. Consequently the development of Red Planet proceeded with this object in view and a calibre of 4.5" was decided upon.

The Military characteristics agreed at the next Tripartite Infantry Conference from 7th - 10th November 1952 did <u>not</u> specify any overmatch requirements. In consequence it was agreed that this British development should continue in the 4.5" calibre only as an insurance against possible up armouring of enemy A.F.V's in the future. Subsequent developments have shown that the weapon was out of step with thoughts in other countries as regards size and weight and the later development work has been limited to proving the weapon and ammunition in a usable form and determining its performance and limitations. The present note describes

briefly the main features of the development and summarises the performance of the weapon in its present form.

3. In the original overall assessment of the Infantry Anti Tank problem four alternative solutions were proposed and work actually proceeded on two rocket solutions known as Red Biddy and Red Planet. The Red Biddy development is described in a note by Major A.G. Stringer[1]. In mid 1953 however, by which time the weapon status was that of an insurance policy it was decided to restrict the development to a single weapon and further work was concentrated on Red Planet.

4. Red Planet

The general arrangement of the Red Planet is shown in figure 1. Because of the strict limitations of weight it was not considered possible that the required penetration could be effected by any other than a hollow charge type head. The ammunition consists of this head connected by means of a suitable adaptor to a high pressure rocket motor and the round is stabilised in flight by a drum tail attached at the rear. With the increased velocity which it was intended should be used in Red Planet it was considered essential to avoid the degradation of hollow charge performance caused by a slow acting inertia type fuze. The head adaptor contains, therefore, a base electric fuze which houses a condenser which is wired in series with the igniter in the rocket motor and the condenser is charged by a hand generator on the projector. On impact with the target the nose switch crushes and this contains two insulated copper contacts connected to the fuze by wires through the copper cone and H.E. filling. The crushing of the nose completes the circuit and the condenser discharges through an igniter which sets off the C.E. pellet, so starting the action of the hollow charge. In a later version the nose switch is replaced by a Barium Titanate crystal which on impact produces the electric impulse required to trigger the igniter. This later system was expected to be even faster than the condenser type in operation.

In the following three sections of this note the development of the three main units:- the rocket motor, the fuze and the warhead will be discussed and in the final section the overall performance of the ammunition in its launcher will be considered.

5. The Rocket Motor

5.1 General Principles

The general intention of the rocket motor was that it should follow the principles used in the U.S.3.5" rocket. In order to achieve a greatly improved chance of a hit however it was intended that the velocity should be increased from the 320 feet per second in the 3.5" rocket, to 600 feet per second or greater if possible. To avoid injury to the firer and to ensure good accuracy it was intended that the propellant should be all burned while the rocket was still in the launcher, over the full temperature range of operation. With the increased weight of the larger calibre Red Planet and the higher velocity the mass rate of discharge had in fact to be increased by a factor of 8 to meet these objectives.

The intention was that the rocket motor should be designed to withstand a test pressure of 20,000 lbs. per square inch but that the working pressure should not be allowed to exceed about 14,000 lbs. per square inch. As compared with the 3.5 inch rocket the web thickness of the propellant had to be reduced to give the shorter time to all burned. In order to compensate for this however, and in the attempt to ensure adequate strength for the high accelerations involved the propellant was made in a trefoil section as shown in figure 2 (a) and was cut into two lengths with an intermediate supporting grid. The disposition of the number of propellant grains in each "stage" of the rocket motor was made

on the principle that the ratio of total propellant burning surface to conduit area available should be the same at the intermediate and at the lower grids and experience when different dispositions were tried showed this principle to be sound.

At one period an attempt was made to design a lighter motor with the charge in a single length only, but the effort available did not permit this design to be pursued.

5.2 Experience with first charge design:

The major difficulty in the design of a high performance rocket motor of the "bazooka" type is associated with the propellant characteristics. The M7 propellant developed by Rohm and Haas has excellent physical properties for this application but in a given rocket motor shows considerable variation in operating pressure and burning time over the service temperature range, giving high pressures at high temperature and long burning times at low temperature. The difficulty is to ensure being all burned in the launcher at the lowest operational temperature while at the same time avoiding high pressures at high temperature, leading to the need for a very heavy motor. Obviously the best compromise must be reached and as an efficiency criterion it may be suggested that the motor design in which the ratio:- $\frac{\text{Maximum pressure at high temperature}}{\text{Maximum burning time at low temperature}}$ is a minimum, is the best design. With this ratio a minimum, then adjustment of the venturi throat size will move the whole pressure (and hence burning rate) range one way or the other as desired.

As stated at para. 5 (i) the first charge design was as shown in figure 2 (a). In actual fact however due to lack of experience with this solvent type propellant the first large batch obtained had the section shown in figure 2 (b). In order to gain experience rocket motors were made up using 38 grains of this propellant and a considerable number of static and projection firings were carried out over the temperature range + 125°F to - 60°F. Typical curves showing the type of pressure and thrust records obtained at the various temperatures are shown in figure 3, while figures 4 and 5 show how rocket pressure and muzzle velocity of the round vary over the temperature range.

It will be observed that the performance as regards the velocity obtained was up to the design target, varying from 620 feet per second at 40°F to 580 feet per second at - 20°F. The throat size of the venturi had been adjusted during the trials to ensure that the maximum working pressure of 14000 would not be exceeded at 125°F. A study of figures 3 and 4 and the results of recoil and debris experiments, to be described later in section 8, revealed several unsatisfactory features however.

Firstly as might be expected at the high max rates of discharge now obtaining, the friction of the high velocity gases in the launcher tube imposed a recoil load on the launcher. Secondly from figure 3 it was observed that the time to all burned is only about 2/3 of the total time to fade out of the pressure. Obviously if we are to reduce recoil to a minimum and eliminate all risk due to slivers of propellant being ejected on to the face of the firer then our objective must be to get complete fade out of pressure within the launcher. It will be noted from figure 4 that the time to fade out at - 20°F is about 32 milliseconds. Since the all burned velocity is 580 feet per second at this temperature the length of launcher required would be nearly 9 feet.

It was obvious that the burning time was too long and this was confirmed by the results of the recoil trials to be described later. It was equally clear however that it would not be easy to bridge the big gap between a 5 feet and a 9 feet launcher without some sacrifice of performance.

Two alternative methods were proposed to improve the situation:-

(i) The possibility of introducing a "choke" device in the form of a streamlined projection to reduce the area available for gas flow in the throat of the venturi, for use only at low temperatures. It was hoped however that the "choke" could be used at a reasonably high temperature without danger so that there could be a good overlap between the temperature at which its use was essential and the safe firing temperature with the "choke" in position. The design was very suitable for this idea since the intention was to bridge the lower grid as shown in figure 6, the screwing in of the choke then being a matter of a few seconds.

(ii) If the choke idea could not be accepted owing to the danger if it were left in at too high a temperature, then the only alternative without major redesign appeared to be to use a propellant grain with a thinner web, probably resulting in a loss of charge weight and a consequent loss in performance.

5.3 Experience with the "Choke":-

The purpose of the choke when used at low temperature was of course to cause a higher working pressure and so to reduce the time of burning. A few preliminary firings were made with a choke fastened to a rod screwed into the upper grid, as this was very easy to do and quickly proved the principle and confirmed the choke size required. This was followed by a series of static and projection firings using the type described above. The results obtained as regards pressures and burning times are given in figure 4 and as regards velocity in figure 5.

From figure 4 it will be noted that the time to complete fade out of pressure has now been reduced from its previous value of about 32 milliseconds to a new value of 23 milliseconds thus getting very much closer to the idea of a 5 foot launcher. It was also found that recoil was acceptable and debris practically non existant even at as low a temperature as -60°F. As regards safety it will be noted that with the choke in position the rocket could not be fired above about 65°F if the working pressure of 14,000 lbs. per square inch was not to be exceeded.

A further useful feature of this design is seen on referring to figure 5. The maintenance of the higher working pressure at the lower temperature reduces the fade off in performance usually encountered, so that with the choke the velocity of the round at -20°F is 605 feet per second as compared with 580 feet per second without.

It was, however, still considered that the risk of firing the rocket above the safe temperature with the choke in position was too great and it was set aside in favour of the reduced charge. It may be noted however, that during the development of the choke, when it was screwed to the grid by a 2BA thread, the choke was blown out at a pressure of 10,000 lbs. per square inch. When the thread size was increased to 5/16" failure of the thread took place at a pressure of 16,000 lbs per square inch. Insufficient work was done to ascertain whether this simple expedient was sufficiently reproducible to form a reliable safety measure. It is felt however that the choke principle is well worth pursuing if a new and improved light weight design is required and no improved propellant becomes available.

5.4 Experience with the reduced web charge:-

Concurrently with the above work on the choke design, supplies had been awaited of a new propellant grain of the form shown in figure 2 (c). The web thickness had been reduced as far as considered desirable if excessive loss in velocity was to be avoided. A comprehensive series of trials, both static and projection, were now carried out with the new charge.

It was possible to get 44 sticks of the new charge weighing about $18\frac{3}{4}$ ozs into the rocket motor as compared with 38 sticks of the original thicker web charge weighing $19\frac{3}{4}$ - $20\frac{1}{4}$ ozs. The total burning surface of this 44 grain charge was greater than that of the 38 grain charge, however, resulting in increased pressures and reduced burning times as shown in figure 7. It will be noted that the total time to fade out of pressure has been reduced to about 25 milliseconds at - 20°F but that the pressure at 120°F has increased to 16,000 lbs per square inch. It would of course have been possible at this stage to adjust the venturi to reduce the pressure at the high temperature but this would have slightly increased the burning time at the low temperature which was already rather larger than had been hoped. It was therefore decided to make a further reduction in the charge weight with the same throat area to bring the pressure to the 14,000 lbs per square inch figure, the consequent reduction in velocity although undesirable, helping nevertheless towards getting the propellant all burned in the launcher.

The propellant charge was therefore reduced to 42 sticks weighing about $17\frac{3}{4}$ ozs and a further series of firings made, the results of which are also shown in figure 7. The pressure at the high temperature end of the scale has been brought to the required value but the time to complete fade out of pressure is increased to about 27 milliseconds. The latter figure is higher than desirable but in conjunction with the drop in velocity did in fact give a substantial reduction in recoil and in ejection of debris at the low temperature end of the scale (see section 8). It will be shown later in fact that with this charge if the launcher length could be increased to 6 feet instead of 5 feet then this charge could be used with safety at all temperatures down to - 60°F. This charge was therefore accepted as the best which could be achieved within the effort justified by the insurance category of the weapon.

It will be noted from figure 8 that the velocity of the round with this reduced charge varies from 555 feet per second at 120°F to 510 feet per second at - 20°F as compared with corresponding figures of 630 and 580 feet per second for the original charge i.e. a loss of 70 to 75 feet per second over the whole temperature range.

5.5 Strength of Rocket Motor:-

In order to achieve the performance required it was essential that a high grade steel be employed for the rocket motor and the steel used does in fact provide a yield strength of 80 tons per square inch as heat treated. At one stage of the development one or two burst motors were experienced but following pressure tests and investigations at Messrs. Crittal Luxfer it was established that in the small batch manufacture then taking place the heat treatment was not being sufficiently closely controlled and in fact in some motors it was shown that the yield strength of the material as treated was only 60 tons per square inch. It was further established that with correct heat treatment there was no difficulty in obtaining a motor which would withstand the full test pressure of 20,000 lbs per square inch. It should be emphasized here that the intention would be that all motor tubes would be tested in production as is done in the 3.5" rocket motor manufacture. This had not been possible during the period prior to the bursts mentioned during experimental manufacture as facilities of the type required had not been established at the small contractor concerned.

Another type of failure which was more persistent was the blowing out of the pressure plate at the head end of the rocket motor on projection firing at high temperature. Again a comprehensive series of hydraulic tests was carried out and it was established that the failures were due to the variation in fit of the 16 T.P.I. screw threads. On one test for example it was shown that one thread .015" below the maximum on effective diameter and .006" down on maximum diameter withstood a hydraulic pressure of 18,000 lbs per square inch whereas another .023 down on effective diameter and .016 down on maximum diameter failed at 16,000 lbs per square inch. It was also pointed out at this time that the method of hydraulic

testing used at Crittal Luxfer was not as severe as a projection firing at high temperatures since the inertia forces on projection imposed an extra load on the thread. In fact with the method of testing then used a 20,000 lbs per square inch test pressure was about equivalent to a projection firing at 14,000 lbs per square inch. An alternative method of supporting on the rim of the tube was devised however which could be used to apply the full load to the thread.

In order to provide an adequate safety factor it was decided to replace the 16 T.P.I. thread by one of 10 T.P.I. and a series of tests was made using three thread forms:- the original 16 T.P.I., a 10 T.P.I. Whitworth thread and a 10 T.P.I. buttress thread. Each thread was tested in three different fits; tight i.e. little clearance; medium .007 - .008 clearance and loose .015 -.016 clearance. The tests established the following results:

(i) With the 16 T.P.I. thread form a test pressure of 20,000 lbs per square inch could only be guaranteed with a tight fit so that this was not a production proposition.

(ii) With the 10 T.P.I. Whitworth form a test pressure of 20,000 lbs per square inch could be obtained with the tight fit, or with the medium or loose fit provided steps were taken to prevent leakage at the thread.

(iii) With the 10 T.P.I. Buttress thread form a test pressure of 20,000 lbs per square inch could be obtained with the light or medium fit, or with the slack fit provided again steps were taken to prevent leakage at the thread.

It was considered that the leakage at the thread in the hydraulic tests could be unimportant in the very short burning time of the rocket at high pressure. In order to check this a number of rockets were prepared with 10 T.P.I. buttress thread form the clearance in the thread varying from .012 to .017, average .014 and these were fired at the static emplacement. It was found that these rounds could be fired with a slightly increased charge $18\frac{3}{4}$ ozs at a temperature of 160°F without trouble the pressure being over 20,000 lbs per square inch. It was therefore considered that this design could be adopted and would give an adequate safety margin in projection firing at 125°F.

6. THE FUZE

6.1 Fuzing Requirements

In addition to the basic requirements quoted earlier in this report the fuze had also to meet other requirements either specified, implied, or imposed by convention or common sense. These include:-

6.1.1. The fuze should comply with accepted standards of safety, ruggedness and moisture-proofing and these should not be impaired by preparation for firing.

6.1.2. The fuze should arm between 10 and 25 yards from the muzzle and be safe to fire through obstructions at lesser distances.

6.1.3. Any round containing a fuze which is pre-armed or otherwise dangerous to the firer should not be capable of being fired.

6.1.4. Any round liable to be blind on target should be incapable of being fired and revealing the firing position.

6.1.5. Misfires must be safe to unload and dispose of immediately.

6.2 Basic Design

The basic principles employed are described in Section 4. A drawing of the fuze and its circuit is reproduced at fig. 9, from which the mode of functioning, and the methods by which the above requirements have been met, may be deduced.

6.3 Development of the Fuzing System

6.3.1. Firing Generators. Contracts to develop suitable generators for charging the fuze condenser and firing the wire bridge type propellant igniters were placed with the General Electric Co., Ltd., and with Barr & Stroud Ltd. Each firm worked on different operating principles and the resulting generators had widely differing electrical characteristics. As both the total energy output and the pulse duration were greatest with the Barr & Stroud generator, A.D.E. Fuze Branch recommended its adoption and modified the fuze circuit characteristics to obtain the maximum benefit from the pulse provided. Both types of generator were subjected to small scale life tests, and again the Barr & Stroud model was found superior.

6.3.2. Condensers It was found at an early stage that the best available commercial tropicalised condensers were not good enough for this task. Their insulation resistance deteriorated rapidly as the operating temperature was raised, and fell to an unacceptable level. A contract was therefore placed with Hunts Capacitors Ltd. to develop a suitable condenser having specified external dimensions, capacitance, and insulation resistance. The outcome of this was a metallized paper type condenser potted in "Marco" resin, encased in two cans and sealed with Araldite. Its insulation resistance at 125°F was well above the value needed for the Red Planet fuze. This condenser passed I.E.M.E. tests and was given type approval.

6.3.3. Cold Cathode Diode Valves. Initially it was planned to use a cheap commercial neon tube, made by Hivac Ltd. The standard tube had to be modified slightly to enable it to withstand normal service rough usage and firing shocks. For early head trials condenser charging was by means of a commercial H.T. battery and was carried out just prior to firing the propellant igniters. Results were, in general, satisfactory. When the first single pulse generators became available it was found that neon tubes completely shielded from external light reacted to the pulse too slowly for charging to take place before the pulse decayed. To overcome this, experiments were carried out using luminous paint, radium sulphate and tritium. Each proved successful but handling hazards, cathode poisoning (barium coating was used) and inspection difficulties then arose and Hivacs were given a development contract to cover further research into this problem. In addition to this, tests were carried out using more expensive diodes, having potassium coated cathodes and already containing an activating agent, made by Ferranti Ltd. A certain amount of electrical tailoring was necessary but the major problem was to produce a tungsten to glass seal which would withstand standard humidity and temperature cycling. Laboratory-produced samples employing oxidized chromium plated tungsten wire proved successful but batch produced samples gave a 1 in 30 failure rate. Development of a suitable production technique is continuing at Ferranti's under the guidance of C.V.D. The measure of success achieved with this diode, coupled with the slow progress of the Hivac "cheap diode" development, led to the latter being abandoned.

6.3.4. Fuze Mechanism. The rocket was originally expected to provide an acceleration of 2,000 g and the detent system was designed accordingly. Later, tests with cold rockets indicated that a 750 g detent was the strongest which would arm reliably, so that design was amended. Whilst, in theory, the new detent system should not pass the standard 12' 6" drop test

in the 65 lb. block it did, in fact, do so due to the cushioning provided by the existing fuze construction.

Delayed arming was achieved by the use of a heavy shutter being driven by a weak shutter spring. After some experimentation a spring was produced which gave an arming distance of around 15 yards.

During firing trials to check arming and to assess arming distance under various conditions, a high proportion of blinds was observed. Shutter carriers were found tobe distorting and preventing arming or maintaining the igniter short circuit after arming; pressure contacts were suspected of being ineffective; and on some heated rounds the filling of the F.85 igniter was found loose in the shutter cavity. The first two defects were rectified satisfactorily, but the last mentioned is an igniter defect which cannot be rectified with the type of igniter employed (the only one available at the time). It is now known that any F.85 igniter which has been heated above 105°F is likely to fail to fire under normal condenser firing conditions regardless of the temperature at which such firing is attempted. The resulting blind round could be projected. This, then, imposed an upper storage temperature limit on the ammunition lower than that of the rocket motor or service requirement.

The initial fuze design had offset initiation of the magazine pellet (for simplicity of manufacture). This feature was disliked, so a two-piece unit providing a "dog-leg" flash channel was substituted. This resulted in borderline shutter sealing at temperatures around 160°F, gas wash between steaming plates being observed, but minor modification eliminated this weakness.

All rounds used during the development of Red Planet had simple double-cap type nose switches protected by steel safety caps. As switch damage was liable to result in a blind round being projected, a new switch having three caps, the outer being earthed, was designed. By arranging for one igniter lead also to be earthed, any damage to the nose switch first resulted in the propellant ignitors being short-circuited.

Waterproofing trials were a failure. Modifications to improve this feature were in hand when it was decided to discontinue development. The modifications being considered may have affected the safe drop characteristics of the detent system, due to modified cushioning, but this was not checked.

6.4 Alternative Fuzing System

6.4.1. Spit-back type. A small quantity of Fuzes No.162 were modified by fitting spit-back magazines. These were tested at Pendine and gave such poor penetrations that this system was abandoned.

6.4.2. Piezo-electric type A small scale trial using piezo electric nose units in place of the nose switch was fired at Pendine, primarily to obtain data on the value and limitations of such units. The base fuzes used consisted of the standard fuze with condensers, diodes and resistors omitted. These fuzes would not have met service requirements for safety. Results, reproduced as Table II, show that increased penetration was achieved. This might be explained by the more rapid firing of the F.85 igniter when swamped with energy.

6.5 Conclusions and comments

6.5.1. The functioning principles employed have been shown to be satisfactory but weak features, such as water-proofing and igniter temperature limitations, require further development before the fuze can be recommended for O.B. trials.

6.5.2. The temperature limitation could be removed by the use of a conducting composition igniter, but the nature of this store and conditions under which it must be assembled would necessitate major alterations to the design.

6.5.3. Waterproofing of the present design is likely to prove extremely difficult. If any major alteration was embarked upon the whole of the waterproofing aspect would be reconsidered. It is not considered reasonable to assume that the rocket motor and head will provide sufficient protection against moisture entry.

6.5.4. The piezo electric solution is attractive since it eliminates some expensive components, simplifies wiring, is less affected by moisture, and would permit the use of a low voltage firing generator. But, elimination of electrical components also eliminates one safety feature for which a substitute would be needed. The nose unit would probably not be graze sensitive. In short, a piezo electric system would entail a fresh start. If, for any reason, a higher striking velocity was required, the advantages of the piezo system over the condenser system would be more pronounced.

7. DEVELOPMENT OF THE HOLLOW CHARGE HEAD

7.1 The Nose Switch

The function of the nose switch for use with the condenser type fuze has been described briefly in para 4 and the switch is illustrated in figure 10. In order to ensure proper functioning and safety with the low capacity condenser it was considered essential that the insulation resistance between the two copper contacts of the switch should have a very high value, specified as not less than 6,000 megohms over the full temperature range. The early materials used in the nose switch construction did not have the desired properties and in a parallel development, a 3.7 inch hollow charge head for an air to ground rocket, premature functioning in a runway trial was attributed to this cause. After a series of investigations polythene and polystytrene were selected for the final trial as the insulating materials. The polystyrene did not stand up to climatic trials so successfully and polythene was selected as the material meeting all the requirements.

7.2 The Hollow Charge Performance

7.2.1. The events leading to the selection of the calibre of 4.5" for the Red Planet were discussed in para.2. It will be remembered that this selection catered for an overmatch of 2" on the specified figure of 6" at 64°. Thus the total penetration expected in the line of the jet was not less than 15.7". With the elimination of the overmatch requirement there has never been any doubt therefore that the service requirement would be met.

During the course of the Red Planet development a very large number of firings of hollow charge heads have been made, firstly using the original 5" head and later the original 4.5" heads and also 3.5". Bazooka heads for purposes of comparison. These trials included performance against armour plate, effects against skirting plates and performance against tanks. The results of these trials are given in a series of Pendine reports some of which are given in the references at the end of this note.[2] It is not however the intention to discuss these here. One illustration is given at figure 11 however as indicating clearly the diminishing effect of the hollow charge inside the target as it approaches more nearly to its limiting performance.

It is proposed rather to limit the results presented to the last two trials, one static trial against stacked plates and the other a projection trial against armour plate, with the 4.5" head in its present form. In presenting these results it may be borne in mind that the designs were completed and the heads filled some time ago and they do not incorporate techniques which have been shown desirable for optimum performance on other work proceeding concurrently. For example a recent note by McKenzie[3] shows the greater consistency of pressed fillings as compared with poured fillings (which the present 4.5" are), also the advantage of modifications in the internal arrangement of the filling and finally the value of increased stand off. The heads do not therefore represent the very best performance using techniques immediately available, but it is nevertheless quite good and well above the minimum required to meet the specification.

7.2.2. Static Trials Against Stacked Plates

In this trial 15 heads to the present design D8/L37119 and 15 heads to an older design DD/L/6688 were fired against stacked ¼ inch mild steel plates. The former heads had been crushed at the nose switch to a degree considered to represent the actual condition as regards stand off, applicable to projection firing, i.e. allowing for the requisite fuze functioning time. The stacks were of 81 plates, i.e. 20¼" high and the heads were placed vertically on these and fired by a suitable electric detonator. Although these tests do not give a precise value of the armour penetration they are very useful in that a result is obtained for each head so that the consistency of performance can be determined and its approximate value. The results of the firings given in Table I below indicate that the two heads did not perform significantly differently so that they can be considered together.

It will be observed that there were three poor results giving penetrations below 16" in two of which the jets are described as being faulty. The remaining penetrations are all in excess of 18" and 8 in fact exceeded the total penetration of the stack available. Counting these latter as only 20¼" the average penetration for the 27 rounds, (i.e. excluding the 3 poor rounds) is 19.1".

7.2.3. Projection firings against Armour Plate

In the projection firings against armour plate which followed at Pendine two types of fuze were used. The first of these was the condenser type fuze originally intended for use with Red Planet and the second was the Barium Titanite with the advantages mentioned in para.4. The objects of the trial were to determine firstly the approximate penetration performance of the head with each type of fuze and secondly the limiting angle for consistent functioning with the barium titanite fuze. The results of the trial are shown in Table 2. Although the numbers fired are hardly adequate for a final assessment the following conclusions can be made.

(i) The head with either fuze easily defeats the minimum target of 6" at 64°.

(ii) The head when used with the condenser type fuze has marginal performance against 8" plate at 60° (16" penetration).

(iii) The head with barium titantie fuze appears to have an improved performance, defeating 8" at 60° and marginally defeating 8" at 62° (17" penetration).

(iv) The limiting angles of the round with barium titanite fuze is about 64°.

Summing up, it can be said that a reliable head is available which with the later type fuze could give an overmatch of 2.5" to 3" on the specified penetration performance.

8. OVERALL WEAPON PERFORMANCE

8.1 Trials to determine the overall ballistic performance of the weapon were of two types. The first type of trial which ran concurrently with the development of the rocket motor was introduced to assess the recoil of the weapon and to ensure that there was not an unacceptable amount of sliver or hot gases projected on to the firer due to gas discharge beyond the front of the launcher. The second type of trial which followed on the freezing of the design was introduced to check the consistency and accuracy of the weapon and to obtain sufficient information to establish preliminary range tables. These two series of trials are summarised in the two sub sections which follow.

8.2 Trials to assess recoil and debris.

To determine the recoil when firing the Red Planet the method first attempted was to rest the projector in a V groove on a suitable mounting, to fix a datum plate to this mounting at the front of the launcher and to connect two brass strips, one at each side to a clamp fitted to the rear of the projector. The two strips thereby acted as tension members to prevent recoil of the launcher and strain gauges were mounted on the strips to measure the recoil forces. The method was not found to give very consistent results however, the main objection being that any spurious side loads on the strips gave strains of the same order of the forces being measured. This method was therefore abandoned in favour of a ballistic pendulum shown diagrammatically in figure 12. In this the launcher is supported from two pivot points and the recoil is restricted by a heavy weight, in this case 160 lbs., hung below the launcher, the movement on recoil being obtained by a suitable pointer moving over a calibrated scale. The scale was calibrated as against the recoil given by a rifle but it should be remembered that the recoil of the Red Planet can be spread over a greater bearing surface and in fact recoils measured as being at least twice that of a rifle can be taken without discomfort. The measurement of debris and blast was simply done by placing suitable cardboard screens in the position of the firer and examining afterwards for damage and debris collected.

The first firings with the ballistic pendulums were carried out using the original thick web propellant charge described in paragraph 5.1. It was found that at low temperature the recoil was excessive, varying from about 5 times that of a rifle at 20°F. to 8 times at − 40°F. The amount of debris was also considered to be unacceptable.

With the same charge and with the choke device fitted on the other hand the debris was negligible even right down to − 60°F. at which temperature the recoil was about 3 times that of a rifle. The velocities obtained with this arrangement varied from 640 feet per second at 40°F. to 584 feet per second at − 60°F.

When the reduced web charge with 42 grains of propellant was used it was found that recoil appeared to be at its worst at about − 40°F. being up to 5 times that of rifle fading gradually to zero at 90°F. There was some debris at the lowest temperatures but not a dangerous amount.

Finally a trial was made with the same charge and varying lengths of launcher and it was found that if the launcher length could be increased from 5 feet to 6 feet the Red Planet could be fired at temperatures down to − 60°F. with a recoil about twice that of a rifle and with negligible debris. Later firings with a different charge lot gave slightly higher recoil.

At one of these trials a "noise" test was carried out which indicated that it was desirable for the firer and any observer within a few feet of the launcher to have cotton wool ear plugs if "singing" in the ears and some pain was to be avoided. With the ear plugs however there were no ill effects at all.

8.3 Range and Accuracy.

During the course of the development a number of dispersion firings have been carried out. At Langhurst in March 1953 for example 10 rounds had been fired at 150 yards from a fixed launcher giving a dispersion of 4 minutes S.D. vertically and horizontally. In May 1953 at Pendine 20 rounds fired at a range of 300 yards gave 3 minutes S.D. horizontally and vertically.

A larger scale firing was made at Langhurst in mid 1955 with the round now approaching its final design. In this trial the rounds were fired at nine different temperatures at a vertical target from 150 yards range. P.C.C. cables were arranged to record the velocity over the internal 340 to 360 feet from the muzzle. Various T.E's were applied to the sight depending on charge temperature and consequent anticipated muzzle velocity. The results were substantially as expected with the T.E's all too low by up to 2 mins of arc as anticipated, since no allowance had been made for loss in velocity due to air drag in flight. From the records it was deduced that there was an average loss of about 14 feet per second for 100 yards range. The grouping of the rounds gave a dispersion of 4 minutes S.D. vertically and horizontally.

A final trial of range and accuracy was made at Langhurst in January 1956. This was much more comprehensive than any other firing and a total of 220 rounds was fired, 5 rounds each at 11 different temperatures and at each of 4 ranges up to 300 yards. For the first time also 4 different propellant lots were used in the same trial. From the results of this trial the graph shown at figure 13 was prepared. The overall dispersion of the rounds was greater than previously being 5½ mins S.D. vertically and horizontally. The increase was probably due to the increased complexity of the trial and the use of the different propellant lots, one lot 113 being dimensionally outside the limits laid down in design.

Following this trial 19 rounds were fired from the shoulder by two observers and there were no ill effects even after one firer had fired 9 consecutive rounds. At this time there were no firings below 20°F. since only the 5 foot launcher was available.

9. FINAL CONCLUSIONS

From the above summary of work it can be stated that Red Planet in its present form is suitable for firing from a 5 foot launcher over the temperature range 125°F. to 20°F. and from a 6 foot launcher down to – 40°F. or even – 60°F. Though not as high as originally planned the velocity is sufficient to give a fair chance of a hit at ranges up to 300 yards. The head performance is more than adequate giving a 3 inch overmatch against the specified target.

10. ACKNOWLEDGMENTS

The work on the rocket motor and warhead described was carried out at different times by Mr. T. P. Forrest and Majors' E. R. Warren and T. D. Corrin. The fuze work was done by Mr. J. H. Bone and Mr. E. W. Croucher.

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1. Infantry Platoon Anti-Tank Weapon "Red Biddy". D2 Tech. Note 6/53, Author - Major A. G. Stringer.

2. Pendine Trial Reports, KX17/1/93, KX17/1/98 and KX17/1/127.

3. Exploration Trials with Pre-pressed Fillings for Hollow Charges. A.R.E. Report 8/53. Authors - D. McKenzie - J. Trower.

TABLE I

4.5" Red Planet - Static Firing Trial

Head Type	Round No.	Penetration Inches of Mild Steel
D8/L/7119	1	$19\frac{1}{4}$
	2	18
	3	$20\frac{1}{4}$
	4	$18\frac{1}{2}$
	5	$20\frac{1}{4}$
	6	$12\frac{1}{2}$
	7	$18\frac{3}{4}$
	8	$20\frac{1}{4}$
	9	19
	10	$20\frac{1}{4}$
	11	$19\frac{1}{2}$
	12	19
	13	$14\frac{1}{4}$
	14	19
	15	$20\frac{1}{4}$
D8/L/6688	16	$18\frac{1}{2}$
	17	$20\frac{1}{4}$
	18	$20\frac{1}{4}$
	19	18
	20	16
	21	$19\frac{1}{4}$
	22	$18\frac{1}{4}$
	23	19
	24	$19\frac{1}{4}$
	25	$18\frac{3}{4}$
	26	19
	27	19
	28	19
	29	$20\frac{1}{4}$
	30	18

1

TABLE II

4.5" Red Planet

Trial with live heads at Pendine 20th-21st March, 1956.

Round No.	Fuze	Plate	Angle to Normal	Result	Entry Hole	Exit Hole
1	Standard	150 m/m.	64°	Penetration, slug lodged	3 x 1¾	1 x ⅝
2	"	"	"	Penetration, clear hole	3¼ x 2¼	1¼ x ⅞
3	"	"	"	Penetration, slug lodged	3 x 2¼	1 x ⅞
4	"	200 m/m.	60°	Penetration, clear hole	2¾ x 1¾	⅞ x ⅝
5	"	"	62°	N.F.H.		
6	"	"	"	Penetration 15" deep	3¼ x 2¼	Bulge 2" x ⅛
7	"	"	61°	Penetration, clear hole	2¾ x 2	⅞ x ⅝
8	"	"	"	Penetration, 9" deep	3 x 2	-
9	"	"	60°	Penetration, 10½" deep	2½ x 1½	-
10	"	"	"	Penetration, 9" deep		
11	Ba-Ti Fuze	"	60°	Penetration, slug lodged	2½ x 2	1¼ x ¾
12	"	"	"	Penetration, clear hole	2½ x 2	1 x ⅝

13	"	"	"	N.F.H.		
14	"	"	"	Penetration, slug lodged	$2\frac{1}{2} \times 2$	$\frac{3}{4} \times \frac{3}{4}$
15	"	"	62°	Blind		
16	"	"	"	Blind		
17	"	"	"	Penetration, slug lodged	$3\frac{1}{2} \times 2$	?
18	"	"	"	Penetration, 9" deep	$3 \times 2\frac{1}{2}$	
19	"	"	"	Penetration, clear hole	$3\frac{1}{2} \times 2\frac{1}{2}$	$\frac{3}{4} \times \frac{3}{4}$
20	"	"	"	Penetration, slug lodged	3×2	$\frac{5}{8} \times \frac{5}{8}$
21	"	"	"	Penetration, clear hole	$3\frac{1}{2} \times 2$	$\frac{3}{4} \times \frac{3}{4}$
22	"	"	"	N.F.H.		
23	"	"	"	Perforation, $5\frac{1}{2}$" deep	3×2	Bulge 2" dia. $\times \frac{1}{4}$
24	"	1" M.S.	70°	Ricochet, Fuze blind		
25	"	"	66°	Ricochet, Fuze blind		
26	"	"	64°	Detonated		
27	"	"	65°	Detonated		
28	"	"	66°	Ricochet, Fuze blind		

* Note Rounds 11 to 14 inadvertently fired with small safety cap on. Rounds 15 and 16 fired with safety cap off, but as result of blanks this was replaced for the remainder of the trial.

It would appear that the maximum angle at which the Ba-Ti fuze will function at 65°.

②

(1)

ROCKET

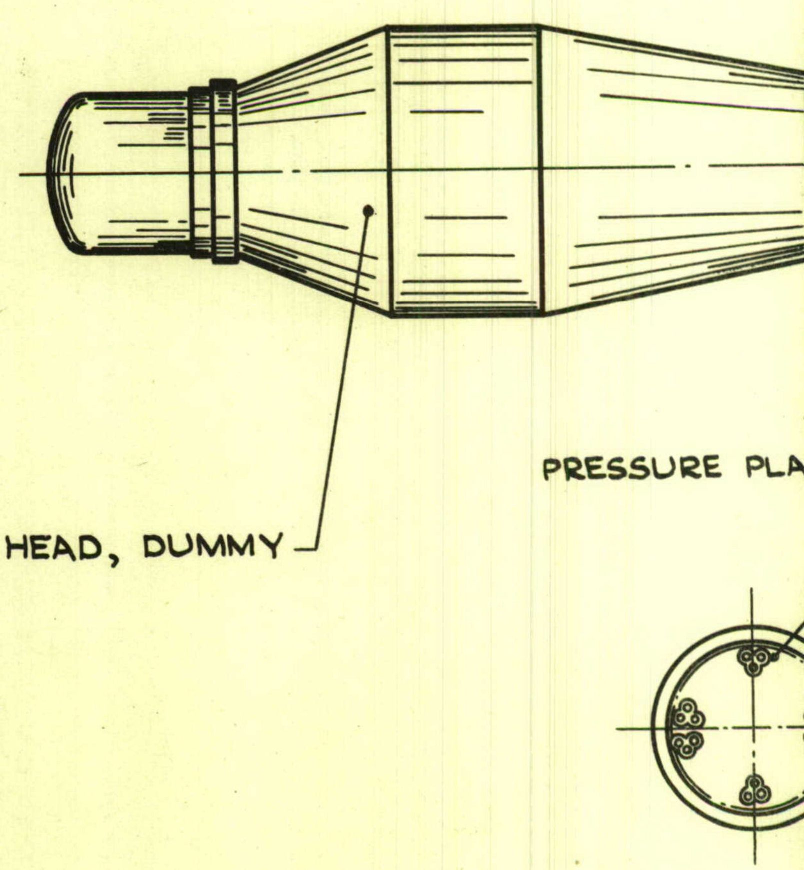

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FIG. 1

DESIGN AS AT FEB.1953.

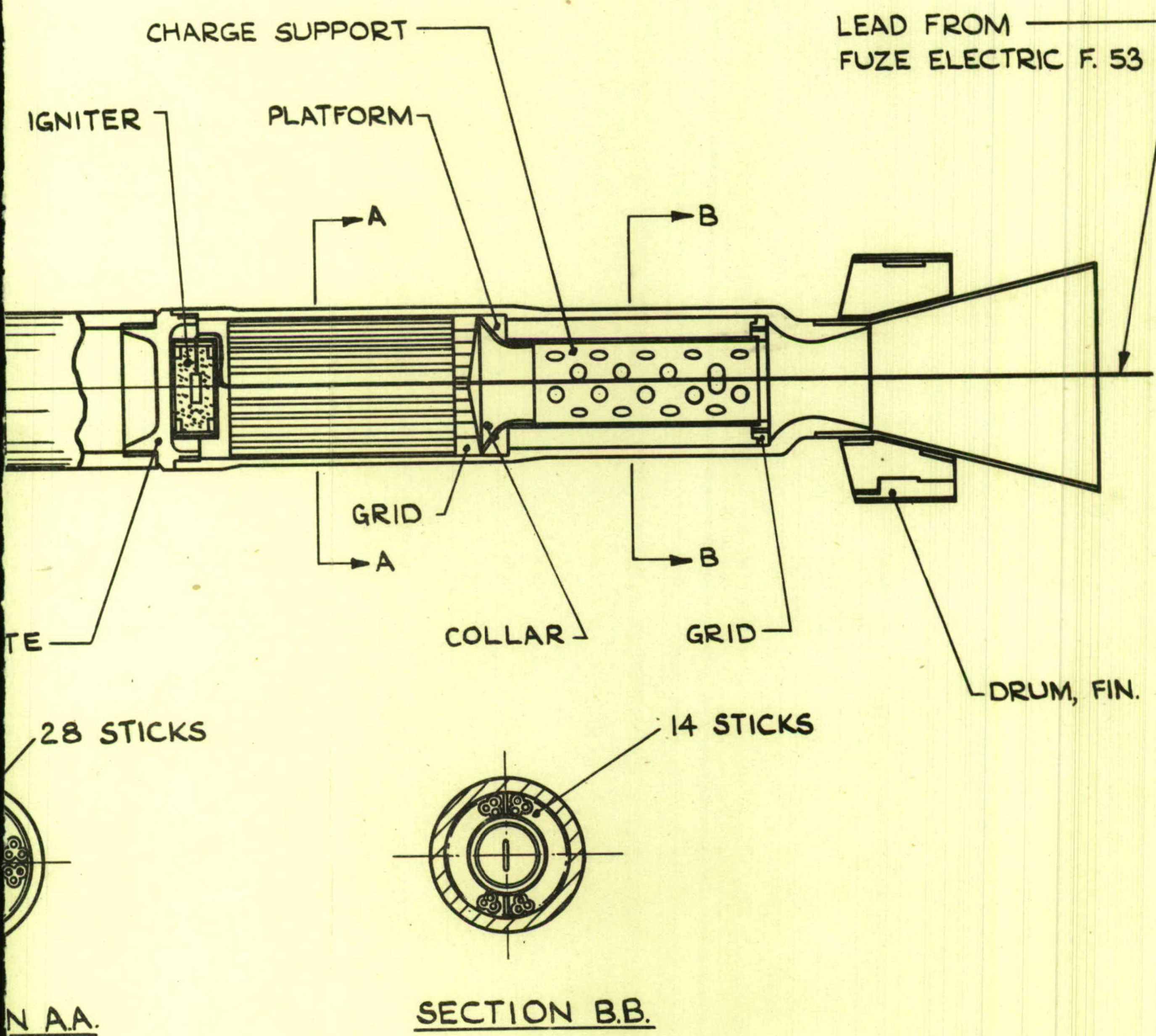


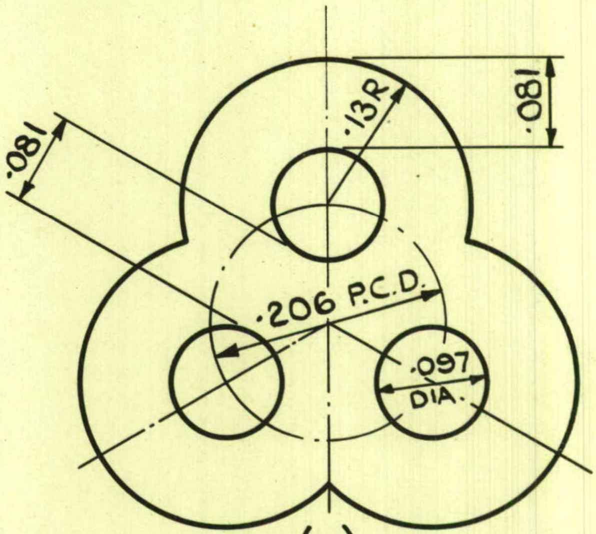
FIG. 2.

CHARGE SECTIONS

D. 8 (L) 7006

AS DESIGNED

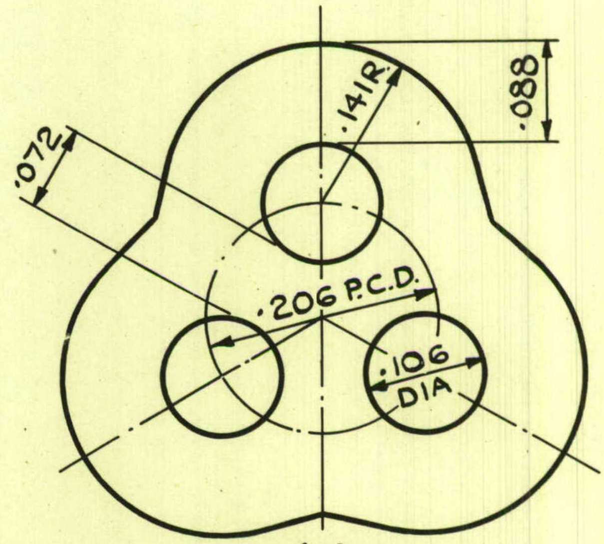
CROSS SECTIONAL AREA
= 1·2 SQ. IN.



(a)

PROPELLANT MADE
TO D. 8 (L) 7006 AS
RECEIVED FROM
R.O.F. BISHOPTON.

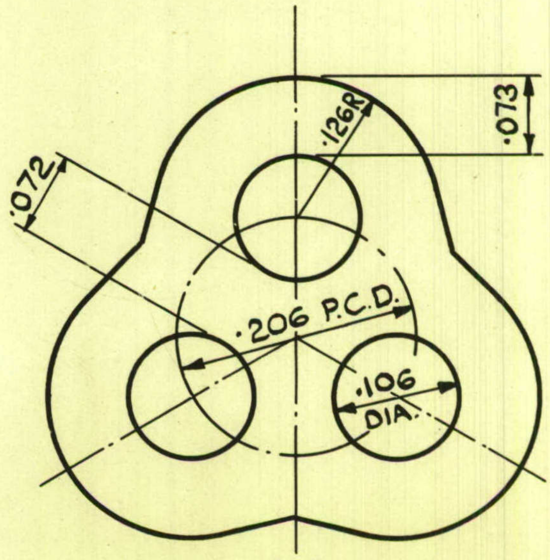
CROSS SECTIONAL AREA
= ·1215 SQ. IN.



(b)

D. 8 (L) 7680 AS
DESIGNED AND
PROPELLANT AS
RECEIVED.

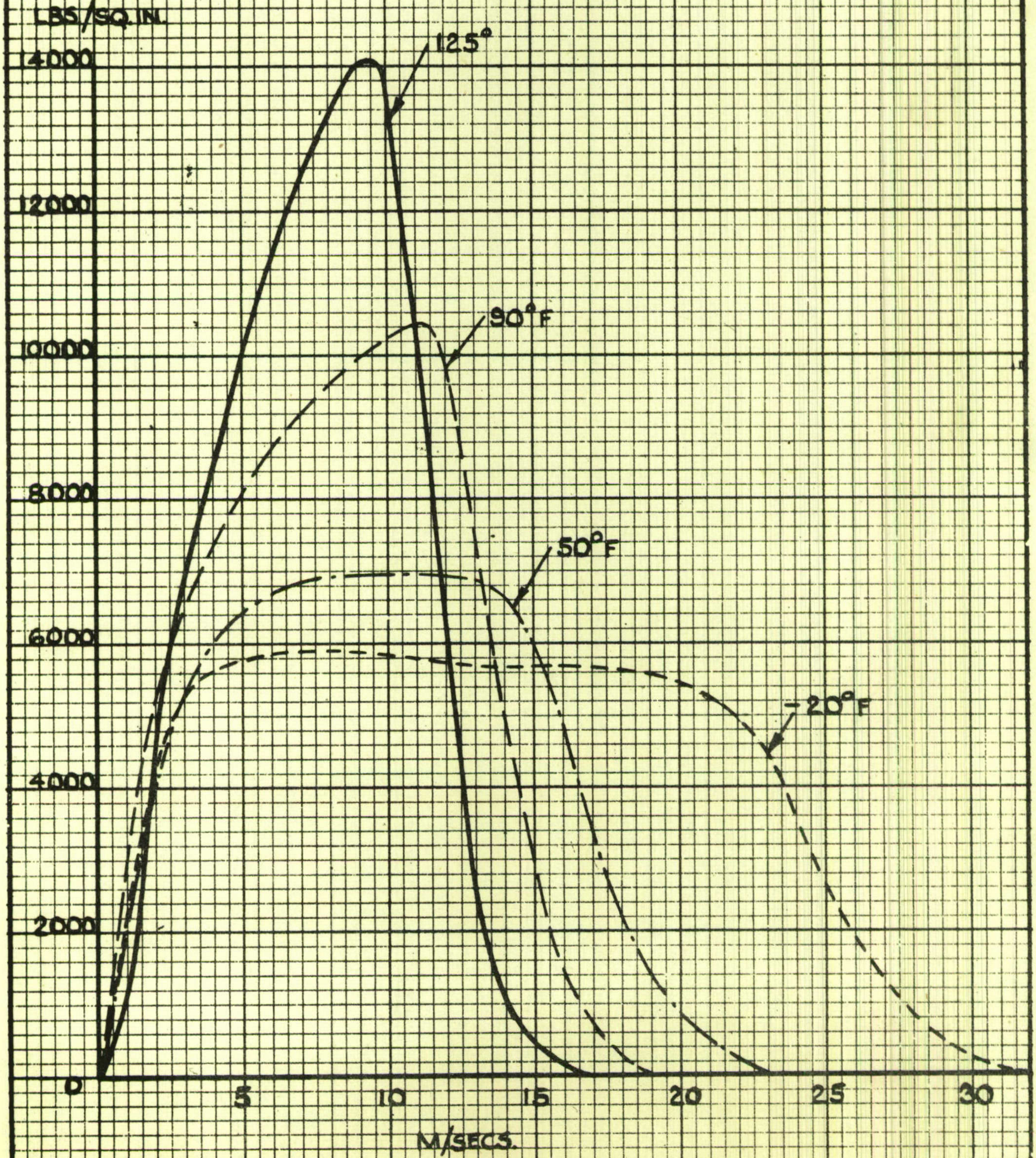
CROSS SECTIONAL AREA
= ·0995 SQ. IN.



(c)

FIG. 3.

TYPICAL THRUST CURVES AT VARIOUS TEMPERATURES.



A.R.D.E. M of S.

RED PLANET

EFFECT OF TEMPERATURE UPON PEAK PRESSURE AND TIME TO FADE-OUT

CHARGE 38 STICKS OF M.7 TO D.S.(L) 7006 - $19\frac{3}{4}$ OZ.

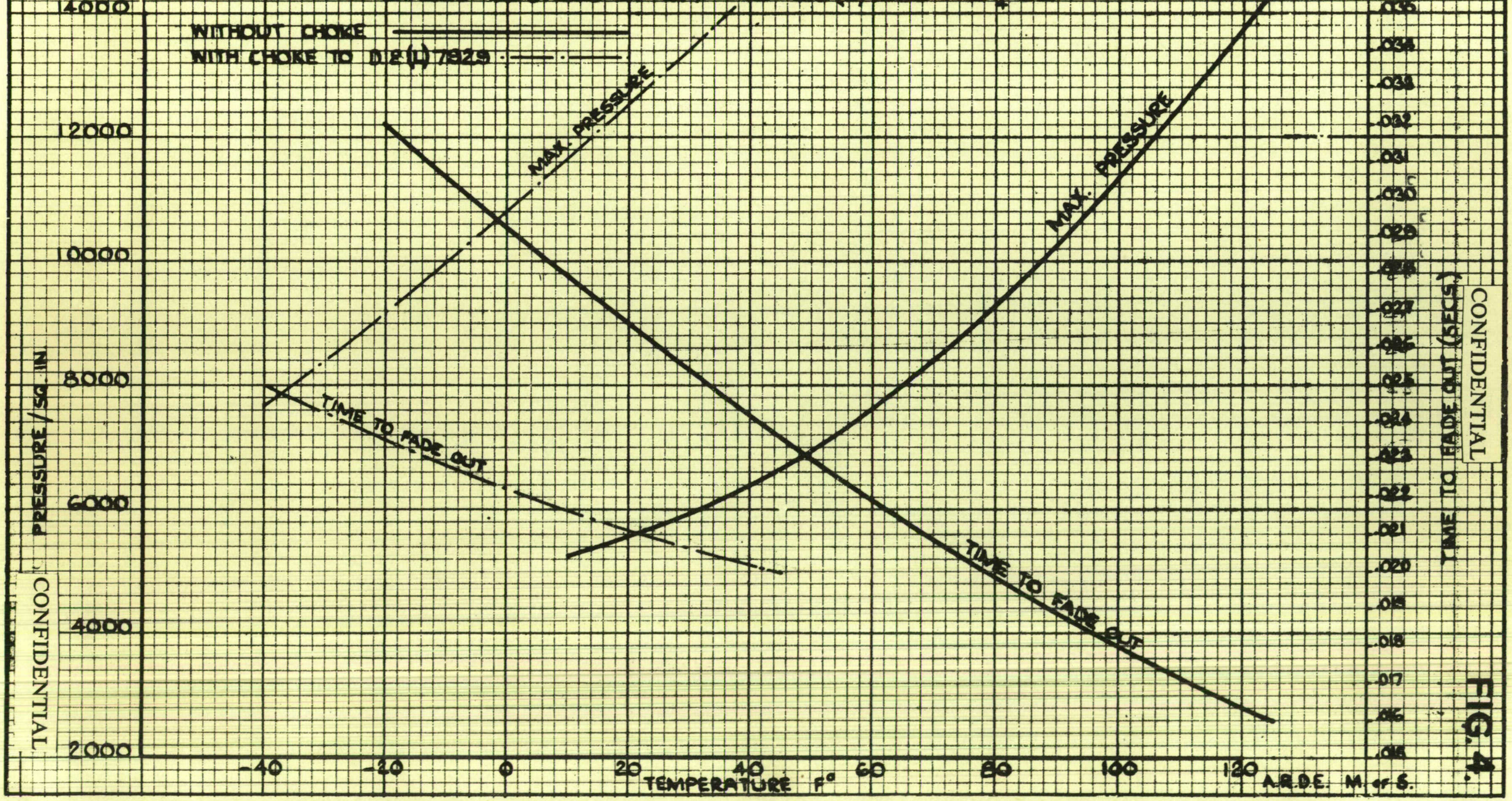


FIG. 4.

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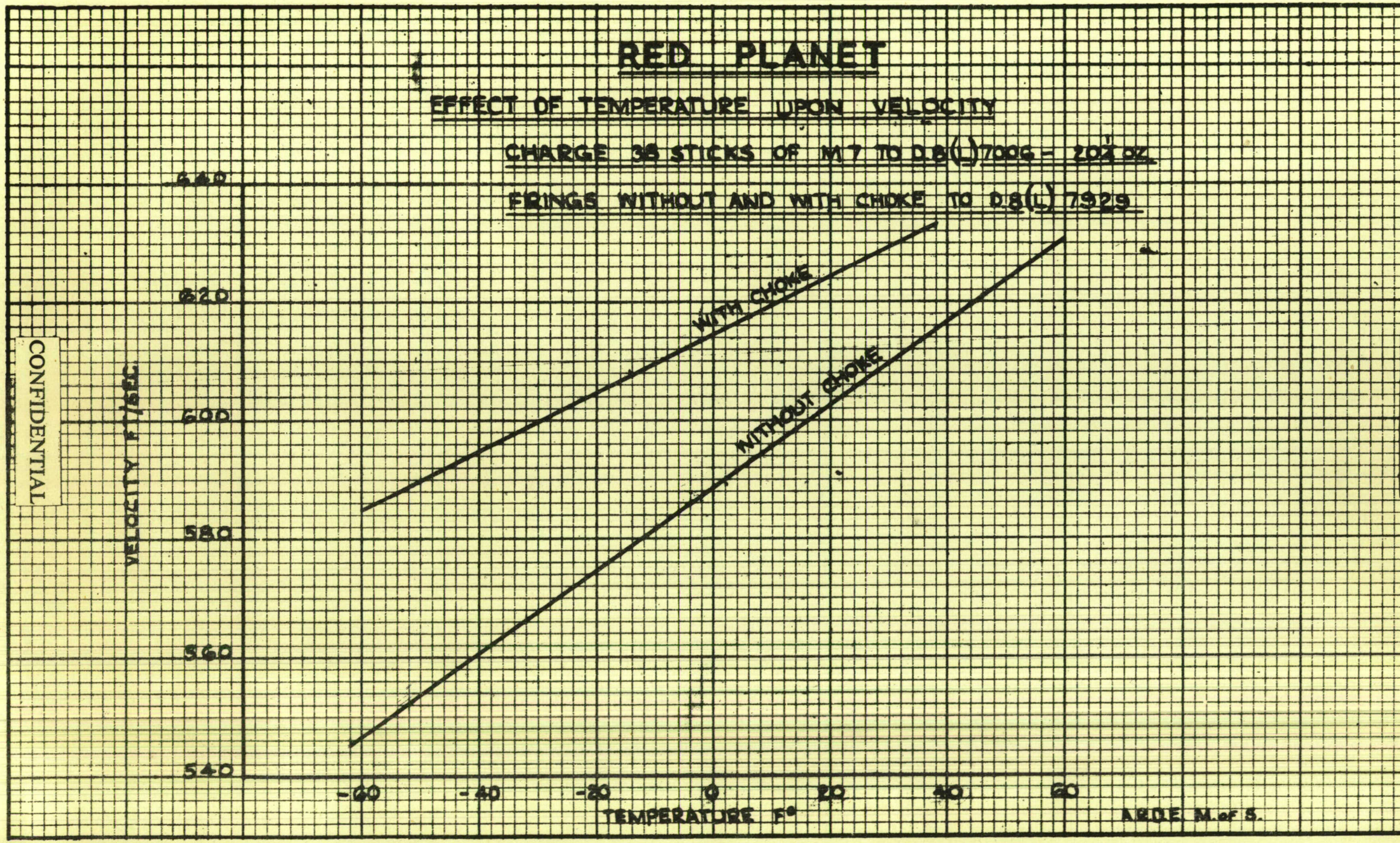

FIG. 5

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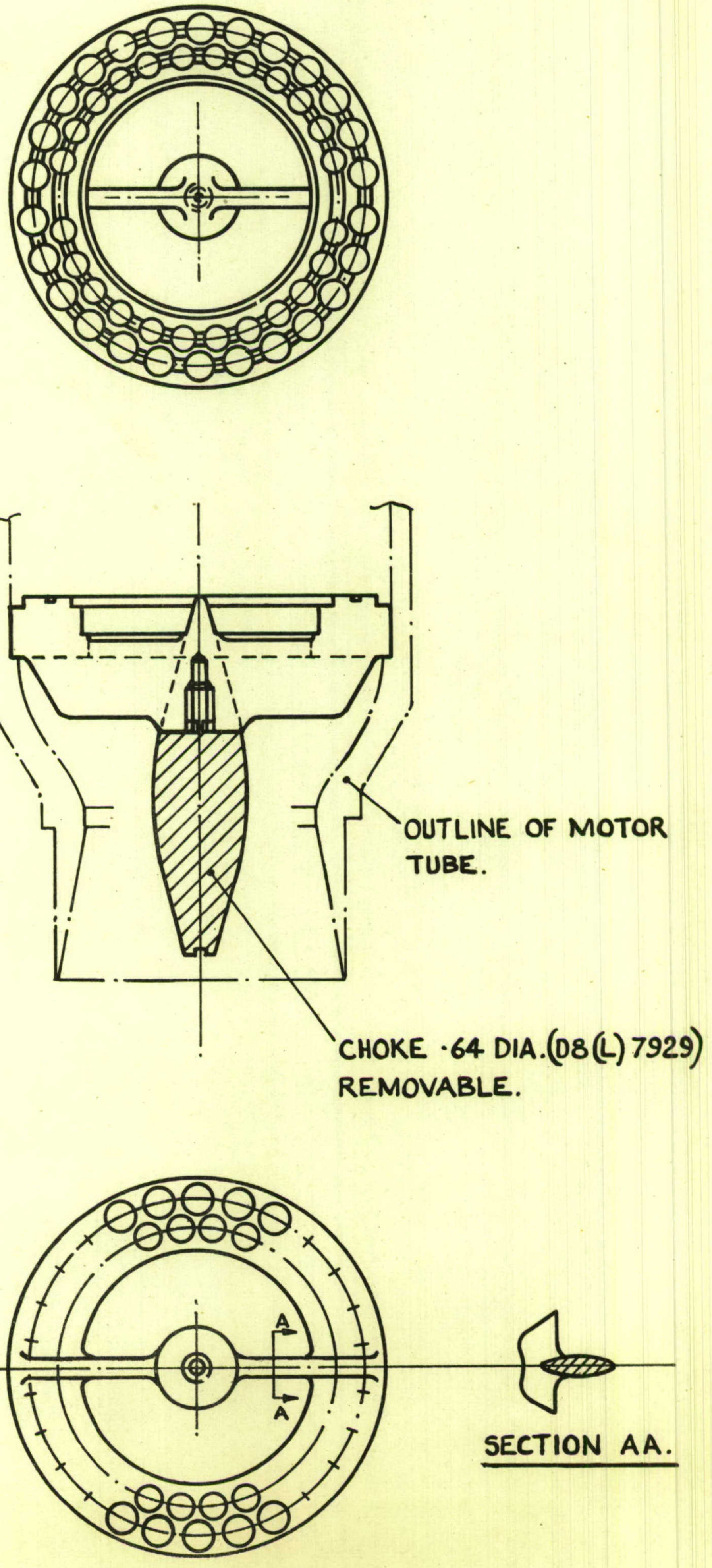
FIG. 6.

GRID No. 2 WITH CHOKE.



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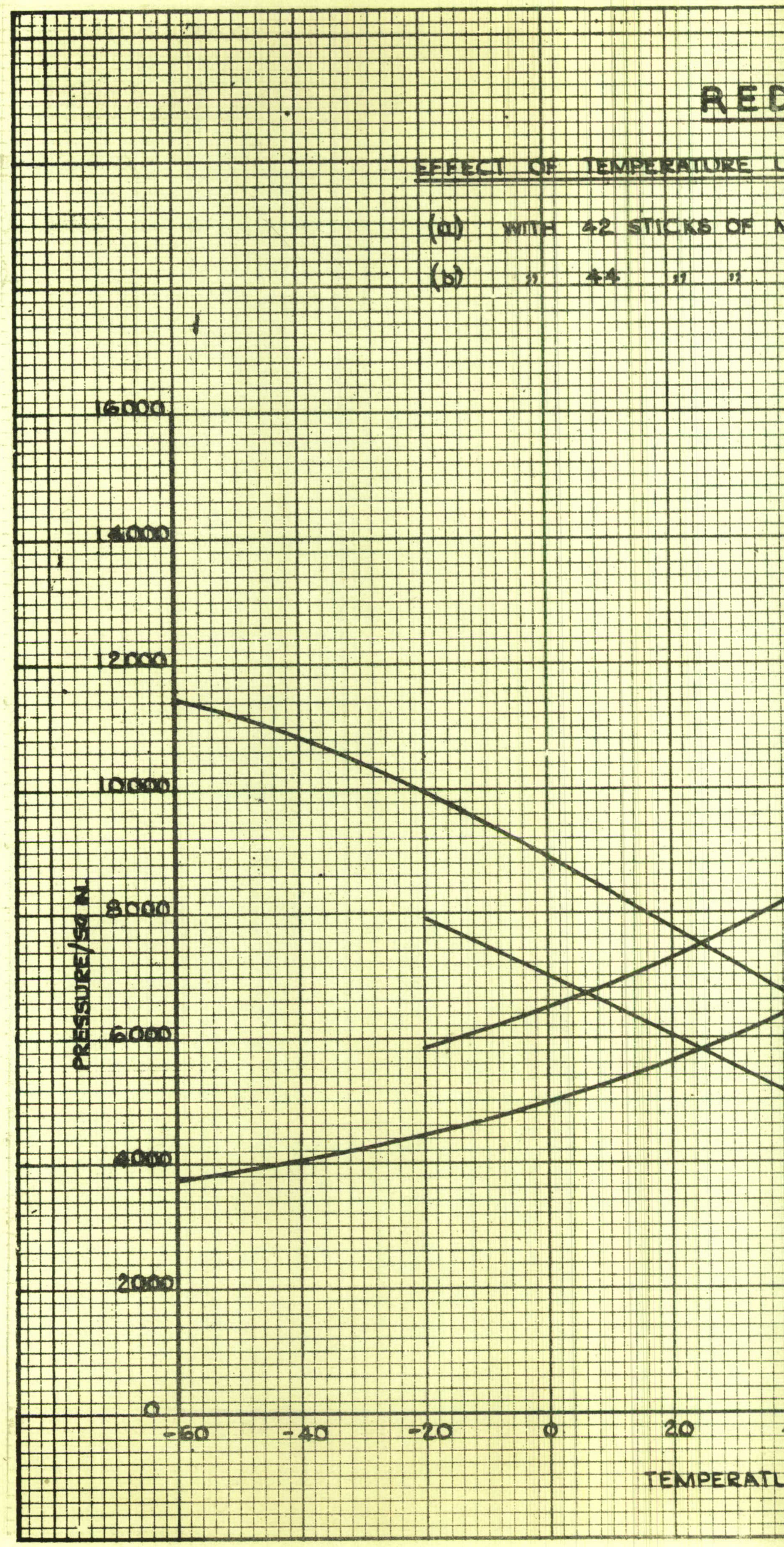

RED
EFFECT OF TEMPERATURE
(a) WITH 42 STICKS OF
(b) " 44 " "
16000
14000
12000
10000
8000
6000
4000
2000
0
PRESSURE/SQ IN.
-60
-40
-20
0
20
TEMPERAT

(2)

CONFIDENTIAL

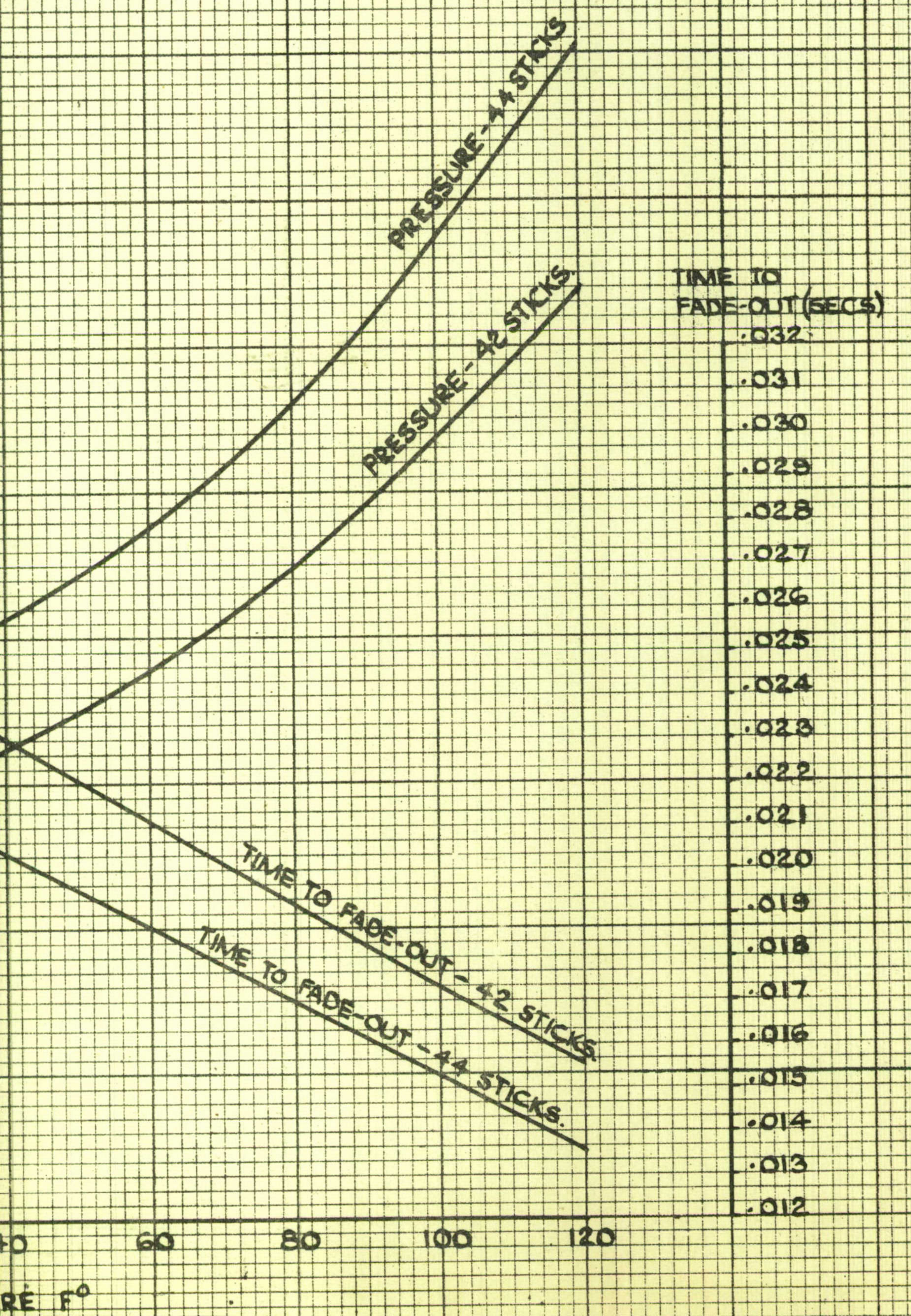
FIG. 7.

PLANET

PON PEAK PRESSURE AND TIME TO FADE-OUT

17 TO D.8 (L) 7680 (28 + 14) – 17 ¾ OZ.

" " " " (28 + 16) – 19 OZ.



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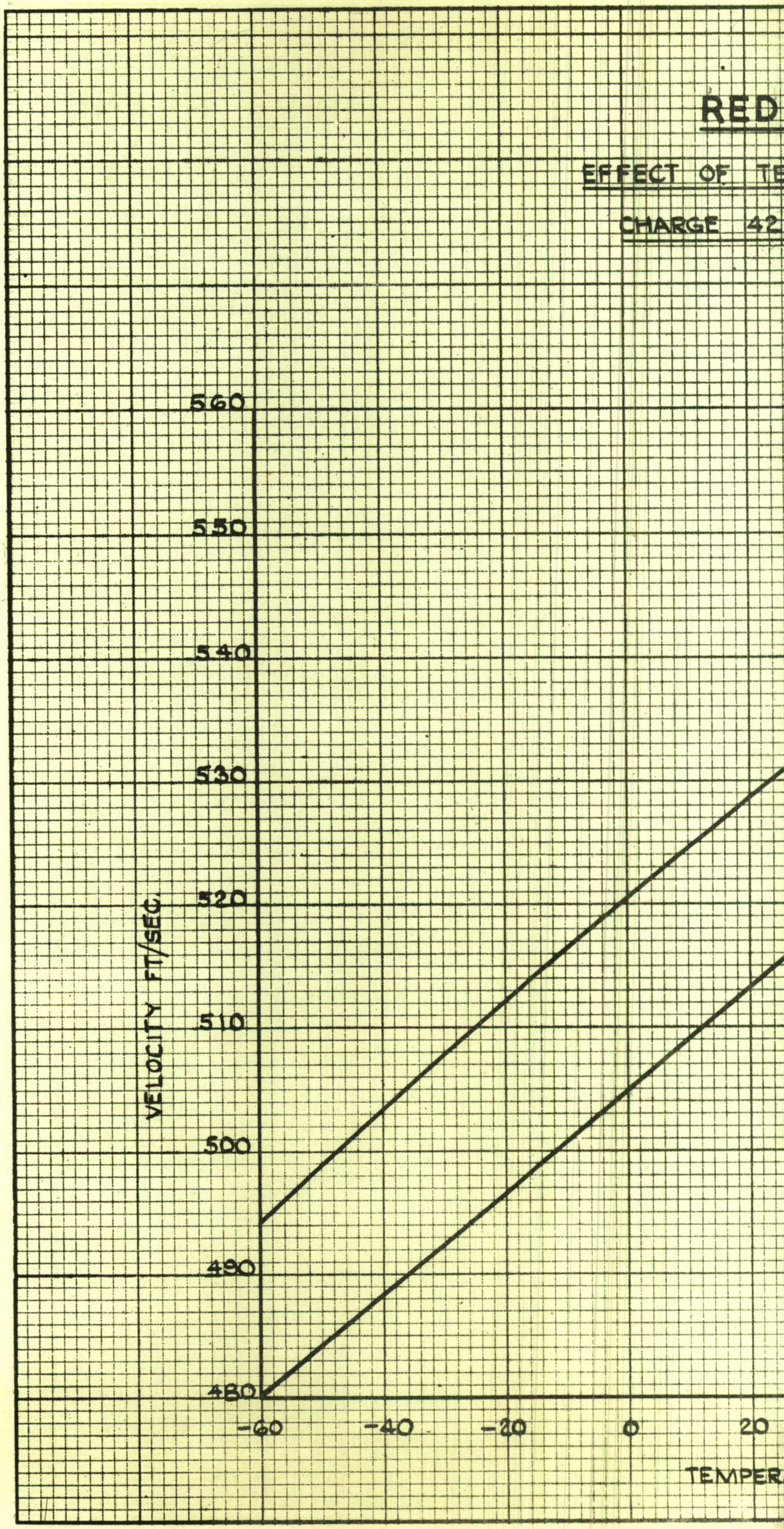
A.R.D.E. M. of S.

1


RED
EFFECT OF TE
CHARGE 42
VELOCITY FT/SEC.
560
550
540
530
520
510
500
490
480
-60
-40
-20
0
20
TEMPER

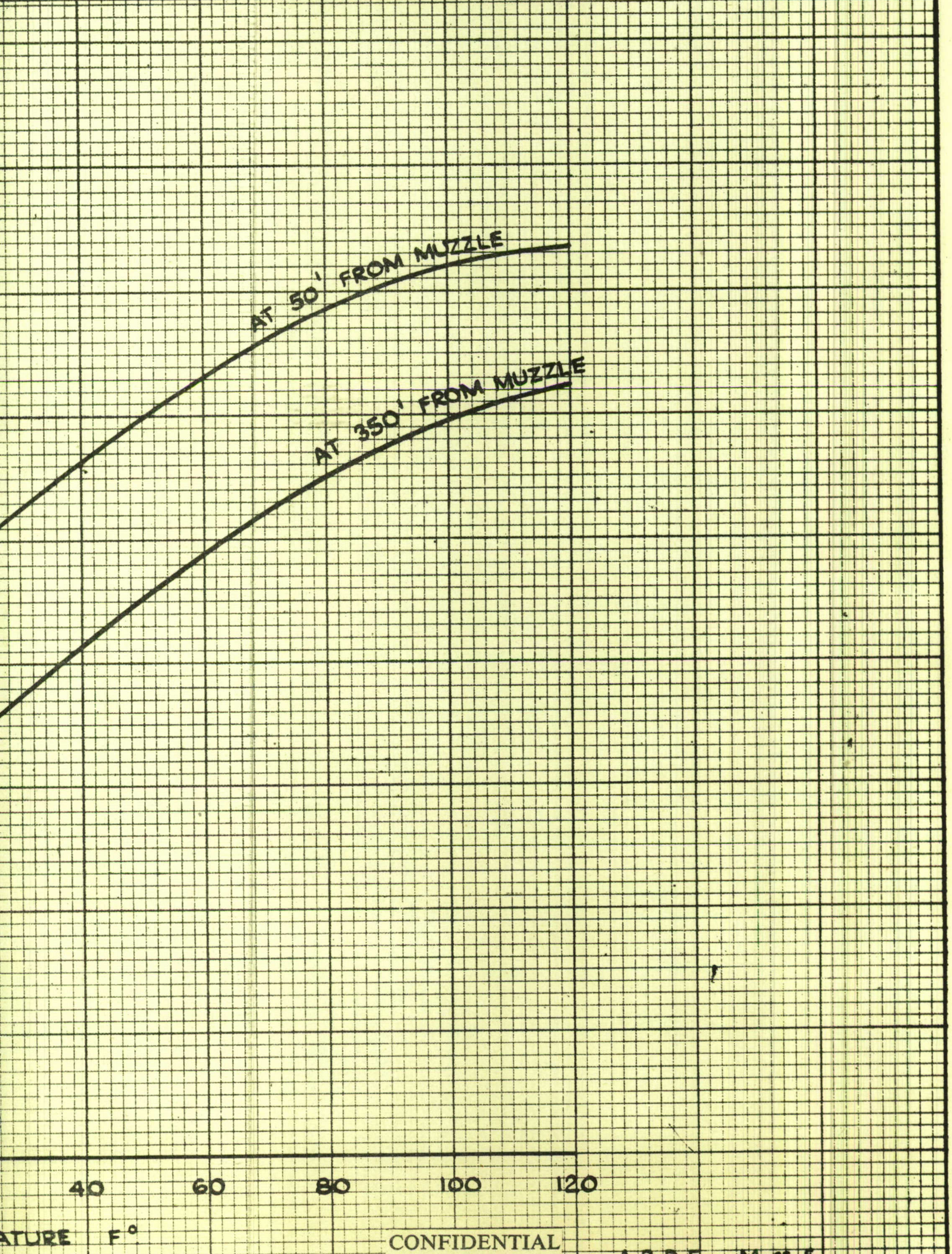
(2)

FIG. 8.

PLANET

MPERATURE UPON VELOCITY

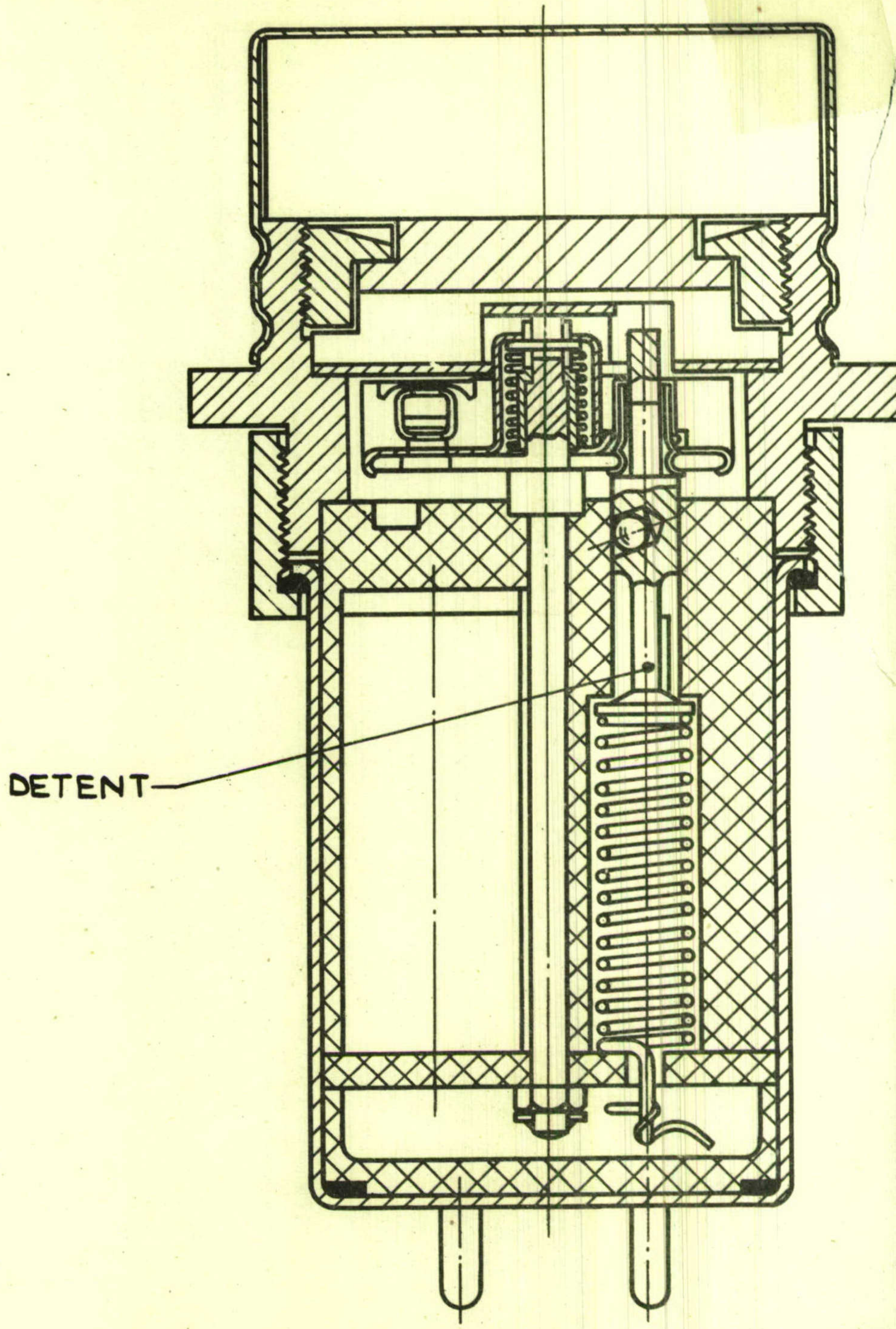
STICKS OF M7 TO D.8(L) 7680 - 17¾ OZ.

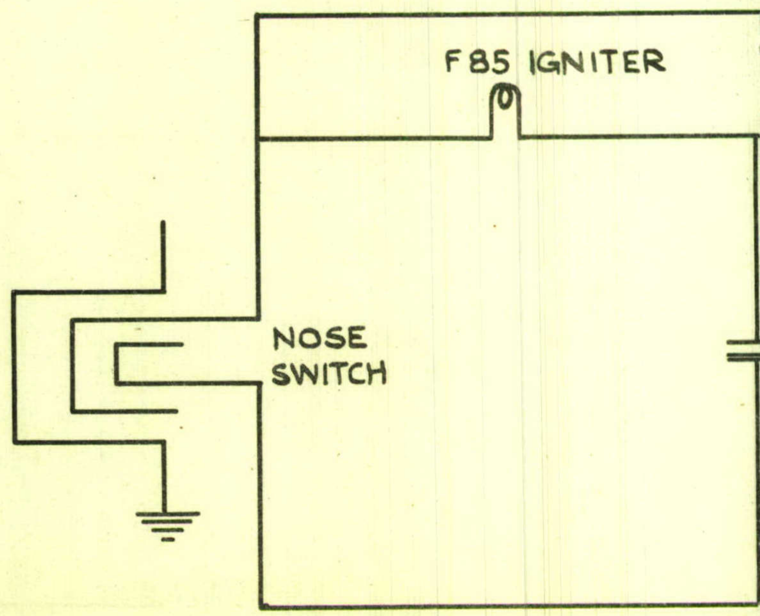


A.R.D.E. M. of S.

1

FUZE BASE E





..LECTRIC FOR RED PLANET.

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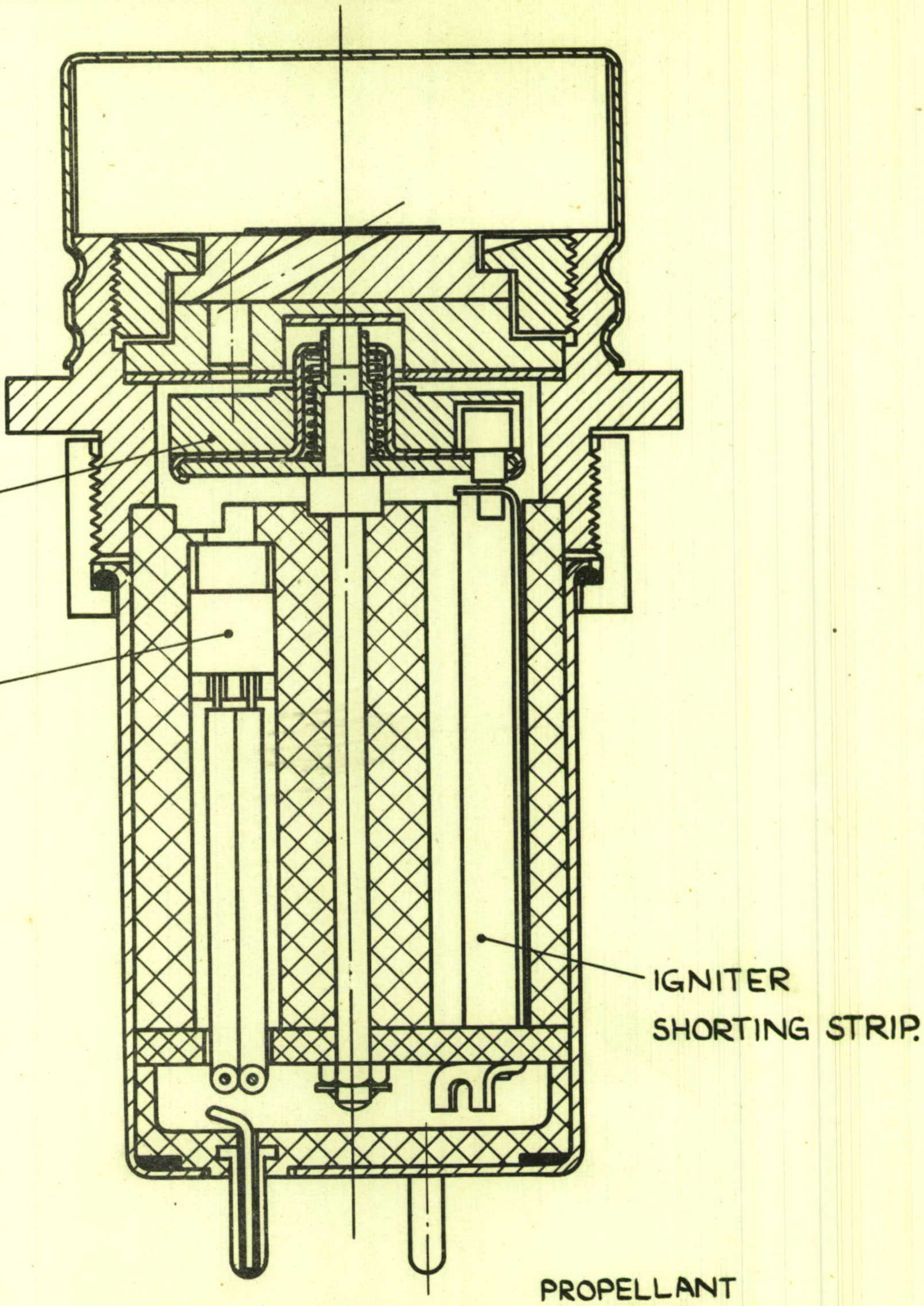
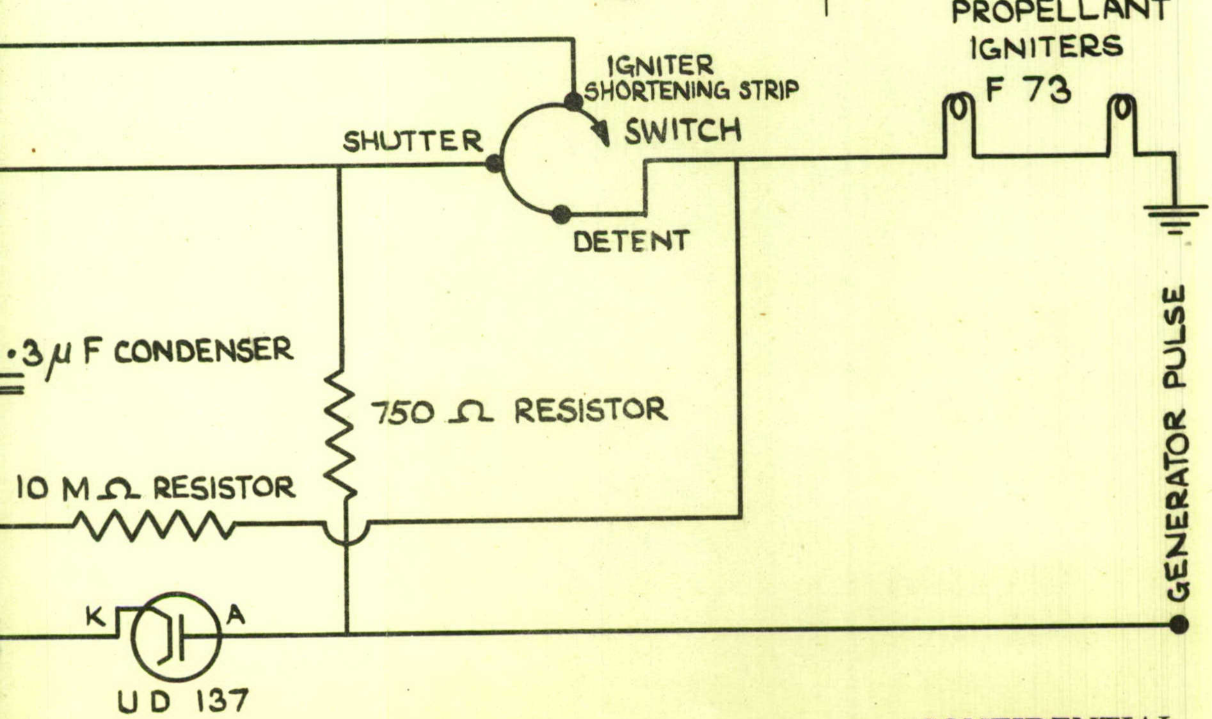
FIG. 9





CIRCUIT DIAGRAM

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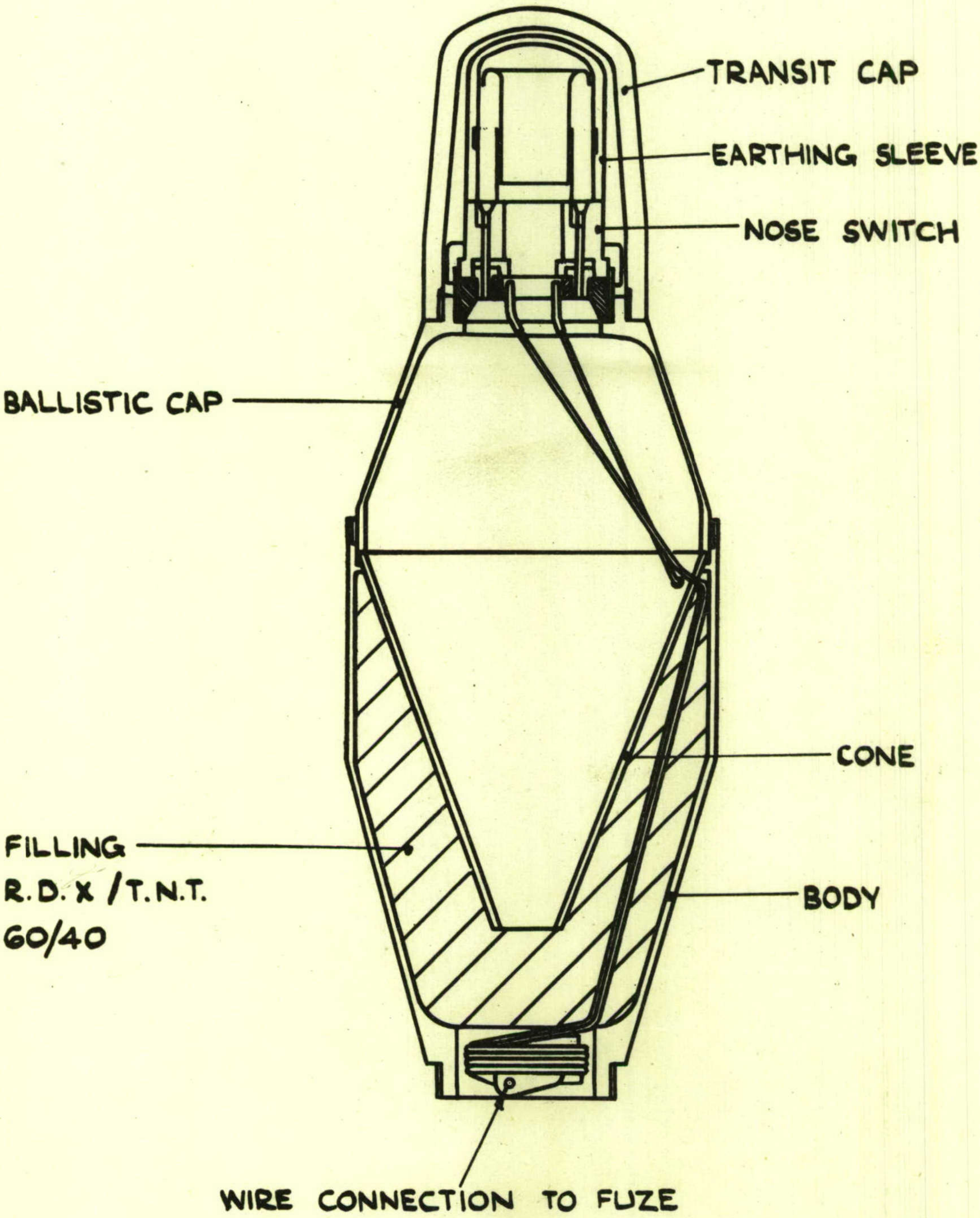
FIG. 10.

HEAD 4·5 / 1·25.



AT 45° TO NORMAL (14·14 IN.)

AT 55° TO NORMAL (17·4 IN.)

AT 60° TO NORMAL (20 IN.)

FIG. 11 DAMAGE TO WITNESS PLATES BY 5 INCH H.C. HEAD AFTER PENETRATION OF 10 IN. OF HOMOGENEOUS ARMOUR PLATE

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(1)

PENDU

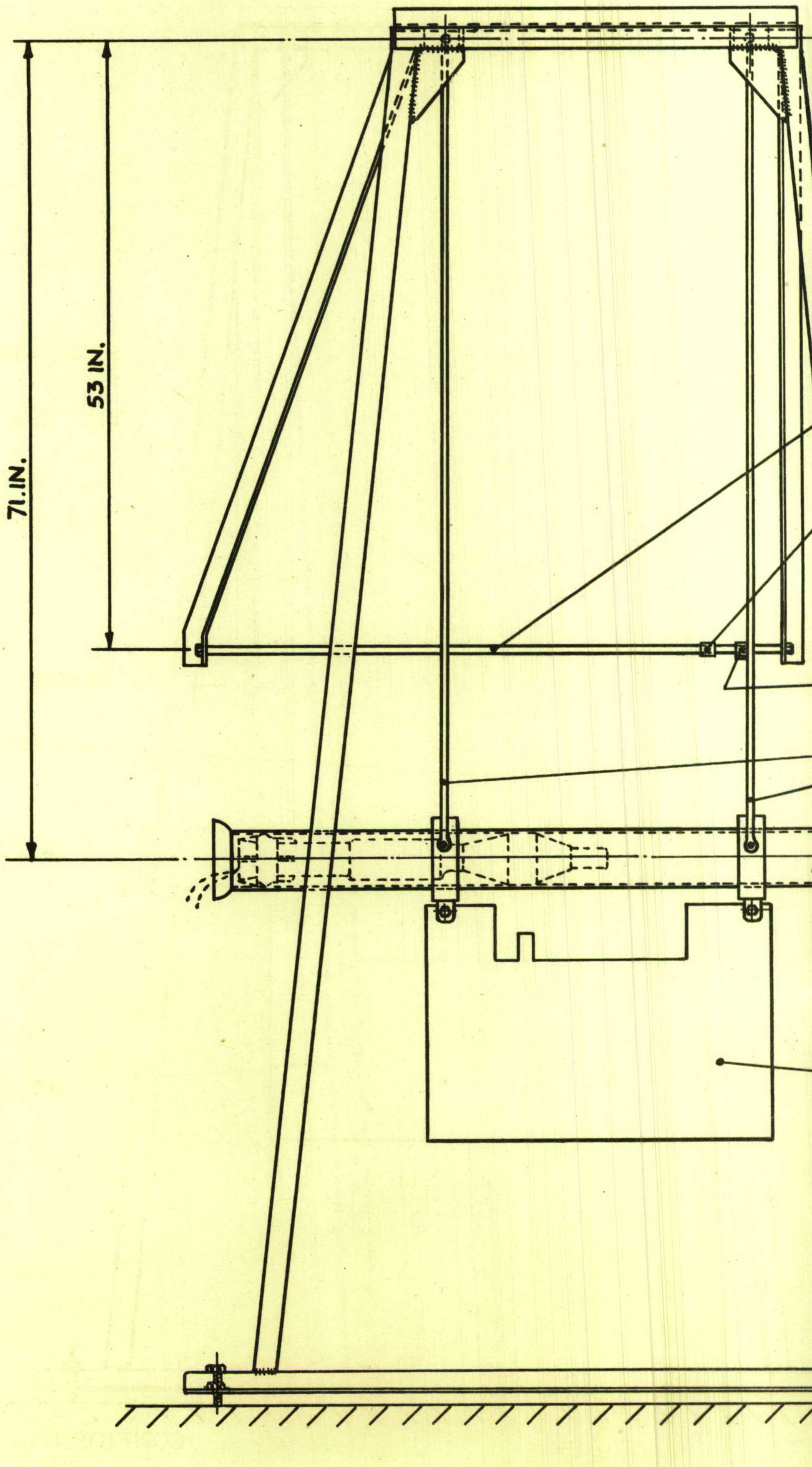
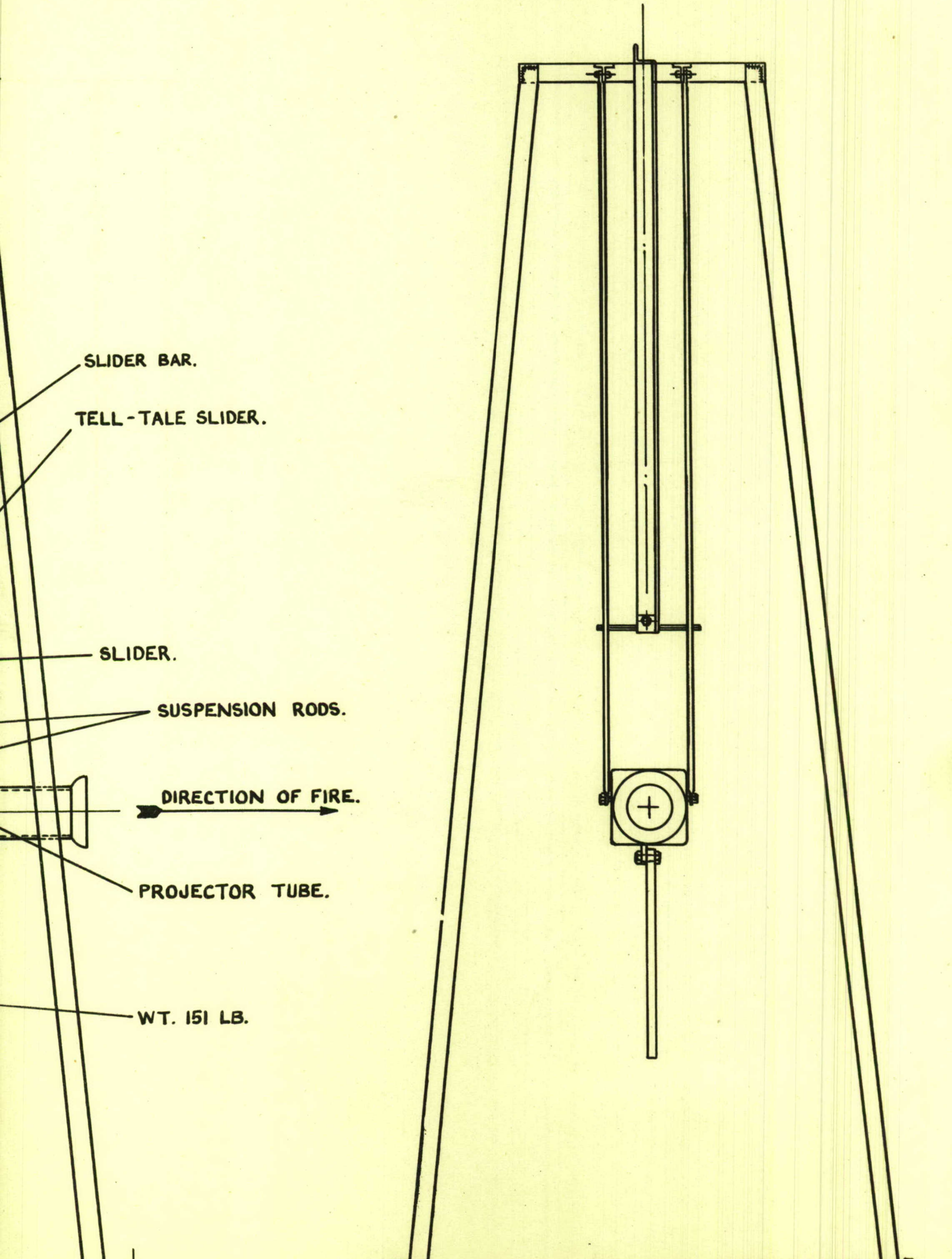


FIG. 12.

LUM PROJECTOR.



SCALE 1/12

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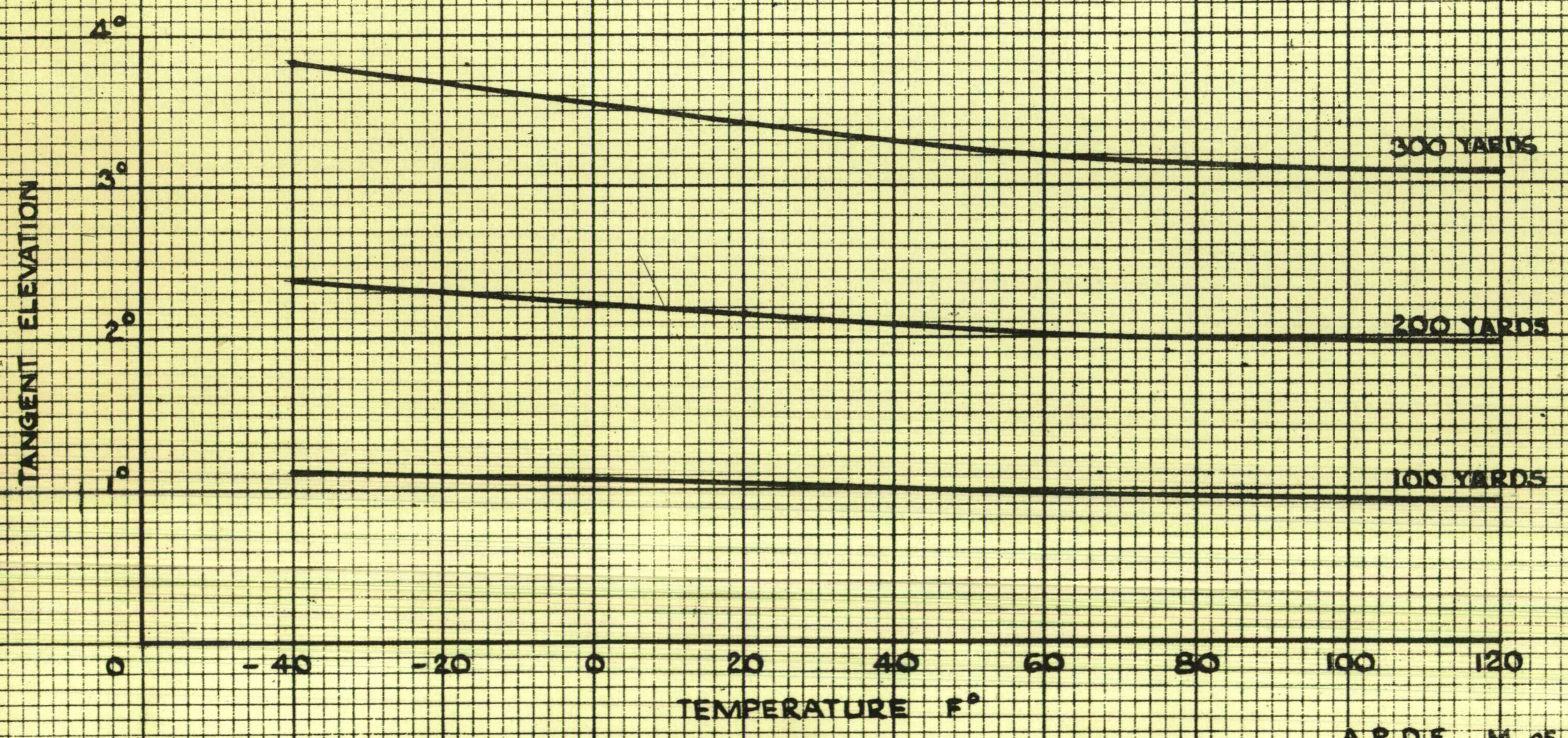
RED PLANET

EFFECT OF TEMPERATURE UPON TANGENT ELEVATION

CHARGE 42 STICKS OF M7 TO D8(1) 7680 - 17¾ OZ.



A.R.D.E. M. of S.

FIG. 13

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[dstl]

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Knowledge Services
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Wilts
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Tel: 01980-613753
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Date of Search: 29 July 2008

Record Summary: DEFE 15/1895
Title: Development of Anti-tank Rocket RED PLANET
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) Report (P) 17/57
Held by The National Archives, Kew

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